California Hydrogen Blueprint Plan

Volume 1 Draft Final Report March 2005

CALIFORNIA HYDROGEN HIGHWAY NETWORK

California Environmental Protection Agency

Acknowledgements

The California Environmental Protection Agency gratefully acknowledges the generous contribution of time and expertise made by members of the Senior Review Committee, the Implementation Advisory Panel, and the Topic Teams (see Appendix B) without whose dedication this plan could not have been produced.

The California Hydrogen Blueprint Plan is submitted to Governor Arnold Schwarzenegger in response to Executive Order S-7-04 by:

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The Plan is presented in two volumes. Volume I contains findings and recommendations to the Governor and the Legislature to begin implementation of the California Hydrogen Highway Network (CA H2 Net). It summarizes what needs to be done to accomplish the goals of Executive Order S-7-04, the estimated costs over the next five years, and recommended next steps. Volume II is a technical report that contains the extensive analysis and findings of the Topic Teams and the Advisory Panel.

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Executive Summary

Background

In the January 6, 2004, State of the State address, Governor Schwarzenegger sent a clear message that California would begin a course toward a sustainable transportation energy future when he spoke the words:

> *I am going to encourage the building of a hydrogen highway to take us to the environmental future...I intend to show the world that economic growth and the environment can coexist.*
>
> *And if you want to see it, then come to California.*

On April 20, 2004, the Governor signed Executive Order S-7-04 calling for the development of the California Hydrogen Blueprint Plan. On the same day he designated the University of California-Davis' hydrogen station as Station #1 of the California Hydrogen Highway Network (CA H2 Net).

Since that time, more than 200 volunteer experts have engaged in the development of the California Hydrogen Blueprint Plan (Blueprint Plan). The volunteers and the organizations they represent are motivated by a shared set of core values that define the vision of a sustainable hydrogen economy for California. These core values are:

- Energy security and national security.
- A healthy environment.
- Economic growth and opportunity for California.

What is the California Hydrogen Highway Network and Why Do We Need It?

The California Hydrogen Highway Network is a State initiative to promote the use of hydrogen as a means of diversifying our sources of transportation energy used while ensuring environmental and economic benefits. To be implemented in phases, the Blueprint Plan outlines a path to 250 hydrogen fueling stations and 20,000 hydrogen-fueled vehicles, which will help set the stage for full-scale commercialization of these technologies.

Hydrogen has the potential to unlock a new energy future for California—a future based on secure, local, and renewable energy sources, accessible and affordable to all Californians, and pollution free. This transition will generate new jobs and new industries and will restore California's control over its energy supply.

Today, as it has been for more than a century, fossil fuels provide a relatively cheap and reliable means to power the vast majority of the world's vehicles. In the last few decades, however, there has been a growing realization that, for at least two reasons, we cannot continue to rely on fossil fuels. First, the supply of

fossil fuels is increasingly insecure. The world is running out of easily accessible petroleum[1] and almost 60 percent of the petroleum imported into the U.S.[2] is from geopolitically unstable areas of the world. Second, the burning of fossil fuels produces pollution that damages human health and generates greenhouse gases that contribute to the unsustainable climate change of the planet.[3]

Hydrogen has the potential to revolutionize the ways we harness the world's energy resources. Hydrogen is both a fuel and an energy carrier. As an emerging transportation fuel, hydrogen is driving innovative new designs of high-efficiency vehicles that offer important environmental and energy diversification benefits. It can be used in fuel cells that are more than twice as efficient as gasoline engines. Fuel cell vehicles (FCVs) have no tailpipe or fueling emissions other than pure water vapor. As an energy carrier, hydrogen can provide electricity where and when needed. Hydrogen can be used in high-efficiency, stationary fuel cells to provide electricity, heating, and cooling for homes and businesses—all with very low environmental impacts.

California is uniquely qualified to play a leadership role in accelerating hydrogen technologies and ensuring that the hydrogen economy moves forward in the smartest way possible. California is already positioned as a world leader in the development and demonstration of hydrogen technologies as evidenced by the California Fuel Cell Partnership, the South Coast Air Quality Management District, the Stationary Fuel Cell Collaborative, the University of California researchers, industries on the cutting edge of technology, and leading national laboratories. A commitment to and an investment in the California Hydrogen Highway Network will help sustain California's leadership position into the future.

Findings and Recommendations

Contained in this Blueprint is a series of findings and recommendations on how to develop the California Hydrogen Highway Network.

Stations

- The development of the California Hydrogen Highway Network should be pursued in three phases. This Blueprint Plan focuses on completion of Phase 1 in the 2010 timeframe.
- Phase 1 calls for deployment of 50 to 100 publicly accessible hydrogen fueling stations sited to provide convenient fueling for hydrogen vehicles. An estimated 2000 hydrogen vehicles can be in operation by 2010 on the way to achieving 20,000 hydrogen vehicles in operation on California's roads and freeways. 20,000 hydrogen vehicles will poise California for full scale commercialization of hydrogen technologies.
- Hydrogen fueling stations should be located in major urban areas near the fleets that are expected to first use hydrogen-fueled vehicles as well as

along major interstates, as much as possible, to facilitate travel between these urban areas.

- An independent review of the California Hydrogen Highway Network effort and the state of hydrogen technologies should be undertaken every two years.

Funding

- Funding to complete the first 100 stations should be provided by the State on a 50/50 match basis with the private sector. The cost to the State for hydrogen infrastructure incentives would be $6.5 million annually for five years.
- Vehicle incentives should be provided by the State during Phase 1. An incentive of $10,000 per vehicle should ensure that 2000 hydrogen-fueled vehicles are operating on California's roads over the next five years. The cost to the State for incentives of both fuel cell and hydrogen internal combustion engine vehicles would be $4.2 million annually for 5 years.
- Cal/EPA should recommend the source of funding and define the return on this investment to the State.

Environmental Goals

- By 2010, the California Hydrogen Highway Network should achieve a 30 percent reduction in greenhouse gas emissions relative to a comparable number of today's fuels and vehicles.
- By 2010, the California Hydrogen Highway Network should utilize at least 20 percent new renewable resources in the production of hydrogen for use in vehicles by 2010 and increase annually thereafter.
- The California Hydrogen Highway Network will be designed to reduce emissions of toxic or smog forming pollutants compared to petroleum-based fuels in use today.

Implementation

- The State should enact legislation and establish policies that help create a business and regulatory climate favorable for establishing a hydrogen infrastructure, including designating hydrogen as a transportation fuel, streamlining and standardizing the fueling station permitting process, and creating an insurance pool for station owners.
- The Blueprint Plan was developed through an unprecedented process of partnership and cooperation with stakeholders that should be continued throughout the implementation of the California Hydrogen Highway Network.

- Cal/EPA should initiate and lead an outreach plan to inform the public of the benefits and objectives of the California Hydrogen Highway Network.

The opportunity to lead the world by fostering the birth of the hydrogen economy is before us. By implementing the recommendations in this report, California will open the door to a sustainable transportation energy future. The phased approach and built-in review process recommended in this Blueprint Plan will ensure a thoughtful, prudent path forward and a responsible level of investment.

1.0 Introduction and Background

On April 20, 2004, California began a course towards a sustainable transportation energy future when Governor Arnold Schwarzenegger signed Executive Order S-7-04 creating the California Hydrogen Highway Network.

Today, as it has been for more than a century, the vast majority of the world's vehicles are powered by fossil fuels. They have provided a relatively cheap and reliable means to power our vehicles. In the last few decades, however, there has been a growing realization that, for at least two reasons, we cannot continue to rely on fossil fuels. First, the supply of fossil fuels is increasingly insecure. The world is running out of easily accessible petroleum[4], and almost 60 percent of the petroleum imported into the U.S.[5] is from geopolitically unstable areas of the world. Second, the burning of fossil fuels produces pollution that damages human health and greenhouse gases that contribute to the unsustainable climate change of the planet.[6]

The good news is that there are solutions. Governor Schwarzenegger has offered a bold three-point vision to solve the problem of petroleum dependence.

In the short term, we must conserve fossil fuels as much as possible. The State has initiated a program called "Flex Your Power at the Pump"[7] to encourage all drivers to take steps to conserve fuel. Simple steps such as driving the speed limit, keeping tires fully inflated, and maintaining a responsible air conditioner setting can greatly reduce fuel consumption.

In the mid-term, we must reduce our use of fossil fuels by encouraging the purchase and use of vehicles such as hybrids, plug-in hybrids, electric vehicles and natural gas vehicles that reduce or eliminate the need for fossil fuels. Last year, to promote the importance of this mid-term strategy, legislation[8] was signed that would allow hybrid electric vehicle owners to use the high-occupancy vehicle ("diamond") lanes. Additionally, the State makes fuel efficiency and emissions performance a high priority in its fleet vehicle purchase policy.

In the long term, hydrogen offers the possibility of energy independence and clean, sustainable transportation. Hydrogen is an energy carrier[9] and fuel that can revolutionize human mobility and the ways we harness the world's energy resources. Hydrogen can be used to power vehicles and provide electricity, heating, and cooling for our buildings—all with very low environmental impacts. It can be produced through a variety of processes using a range of feedstocks, including natural gas, methanol, ethanol, biomass, and water. As an emerging transportation fuel, the promise of hydrogen is driving innovative new designs of high-efficiency vehicles that offer important environmental and energy diversification benefits.

1.1 Executive Order S-7-04

In April 2004, the Governor signed Executive Order S-7-04 (Appendix A), which formally launched an important new hydrogen initiative as part of California's energy and environmental plan. This executive order calls for:

- Designation of California's 21 interstate freeways as the "California Hydrogen Highway Network."
- Planning and build-up of a network of hydrogen fueling stations along these roadways and in the urban centers they connect so that by 2010, every Californian will have access to hydrogen fuel.
- Accelerating progress in hydrogen use through public incentives and financing mechanisms, such as general obligation bonds, or revenue bonds with repayment mechanisms; joint power agreements; and partnerships with public and private entities.
- Promoting economic development opportunities resulting from increased utilization of hydrogen for stationary and mobile applications.

1.2 Development of the Blueprint Plan

Cal/EPA led a collaborative process to develop a Blueprint Plan to implement the California Hydrogen Highway Network (CA H2 Net). To manage this effort, Cal/EPA established an Executive Order Team[10] (EO Team), chaired by the Cal/EPA Secretary. The EO Team respectfully accepted the counsel of a Senior Review Committee consisting of senior State government officials, and an Implementation Advisory Panel consisting of high-level representatives from industry, California State agencies, federal and local government agencies, academia, and public advocacy groups.[11] The Advisory Panel worked closely with the EO Team and the Topic Teams to provide the basis for the recommendations and Action Plan to implement the CA H2 Net.

Volunteer experts provided invaluable and detailed technical, financial and policy inputs that helped shape the Blueprint Plan. These volunteers represented a wide array of government agencies, private industry, academia, and environmental organizations. More than 200 individuals served on five separate "Topic Teams": Rollout Strategy, Societal Benefits, Economy, Implementation, and Public Education[12]. Each of the Topic Teams submitted an independent report to the EO Team—all are publicly available.[13]

Over the course of about six months, the five Topic Teams, Advisory Panel and EO Team worked together to develop the basis for the Blueprint Plan. The five Topic Teams performed detailed analyses, solicited input and vetted their findings at public meetings, and presented key conclusions to the Advisory Panel. The Advisory Panel guided the work of the Topic Teams based on their wisdom and experience. The EO Team shaped the recommendations in the California Hydrogen Blueprint Plan based on a series of agreed upon statements from the Panel that were supported by the findings of the Topic Teams.

The California Hydrogen Blueprint Plan is a two-volume document accompanied by five independent reports from the Topic Teams. Volume I contains the EO Team's recommendations to begin implementation of the CA H2 Net. Volume I summarizes an Action Plan, the estimated costs to the State over the next five years, and recommended next steps. Volume II contains key findings of the Topic Teams and the corresponding counsel of the Advisory Panel in support of the recommendations in Volume I.

The Blueprint Plan will be updated every two years in accordance with Executive Order S-7-04. The updates will be critical to ensure that the CA H2 Net promotes an accelerated and intelligent transition to a hydrogen economy.

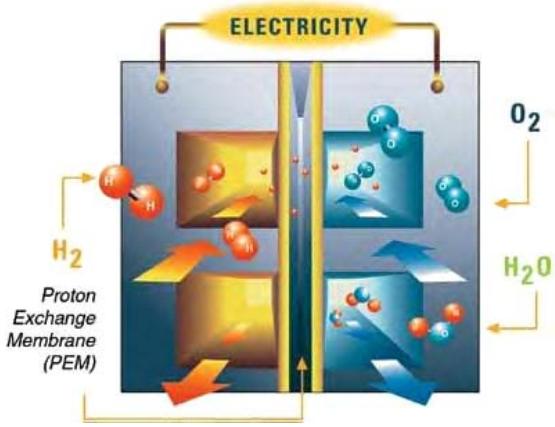
1.3 Basic Description of Hydrogen and its Uses

Hydrogen is the simplest and lightest element. Although hydrogen is all around us and accounts for 75 percent of the entire universe's mass,[14] on Earth it is found only in combination with other elements. For example, hydrogen readily bonds with oxygen to make water, and with carbon to make organic matter. Before it can be used as a fuel, hydrogen must be separated from these other elements. The process to "produce" hydrogen requires energy, just as it takes energy to make other transportation fuels like gasoline and to compress natural gas. For example, hydrogen can be produced from molecules called hydrocarbons by applying heat. This "reforming" process is currently used to make hydrogen from natural gas and is the cheapest method of hydrogen production. An electrical current can also be used to separate water into its components of oxygen and hydrogen in a process called electrolysis. In addition, certain types of algae and bacteria use sunlight as their energy source and give off hydrogen under certain conditions.[15] Hydrogen gas exists in the form of two tightly bound hydrogen atoms (H_2).

Today, hydrogen is primarily used for industrial processes such as ammonia manufacturing and petroleum refining. It has also been widely used in NASA's space program as fuel for the space shuttles, and in fuel cells that provide heat, electricity and drinking water for astronauts.

A fuel cell is an elegant and simple device that produces a direct and continuous current of electricity using an electrochemical reaction between hydrogen and oxygen. All of the world's major automobile manufacturers are developing hydrogen fuel cell vehicles because of the incredible potential fuel cells hold as a commercially viable, clean and efficient power source. Stationary applications of fuel cell systems can be used to generate environmentally friendly electricity and usable heat. In both of applications of fuel cells, California is likely to be the earliest U.S. market for commercialization. Figure 1 illustrates how a PEM fuel cell converts hydrogen and oxygen into electricity.

Proton exchange membrane (PEM) fuel cells are the type most commonly used for automotive applications.



Graphic courtesy California Fuel Cell Partnership

When hydrogen enters a PEM fuel cell, its electrons and protons are separated. A membrane in the cell selectively allows the protons to pass through, while the electrons are routed to provide the electricity to power the motor that propels the vehicle. On the other side of the membrane, the hydrogen combines with oxygen from the air to form water and heat.

Figure 1—Basic Operation of a Proton Exchange Membrane (PEM) Fuel Cell

Fuel cell vehicles are in fact electric vehicles (EVs). Like battery-powered EVs, fuel cell vehicles use efficient and fast response electric-drive systems. However, instead of electrons being stored in the chemicals in the battery, the electrons are released in the fuel cell by way of a reaction between hydrogen and oxygen. Fuel cells can be thought of as batteries that never lose their charge -- hydrogen can be continuously supplied from an external fuel tank, and oxygen can be extracted from air. The simplicity of fuel cells impart many desirable attributes to fuel cell vehicles including zero emissions, fuel economy that is twice as high as most internal combustion engines that we drive today, a driving range required by consumers and refueling times comparable to gasoline vehicles.

Figure 2 illustrates the basic operation of a hydrogen fuel cell vehicle powered by a proton exchange membrane (PEM) fuel cell, which is the type being developed for automotive applications. While today's prototype fuel cell automobiles appear similar to conventional vehicles on the outside, the drive train components and their layout can be quite different. The challenge most cited by experts as a potential shortcoming of hydrogen vehicles for consumers is the storage of enough fuel so that a hydrogen vehicle's range is similar to that of a traditional internal combustion engine vehicle.

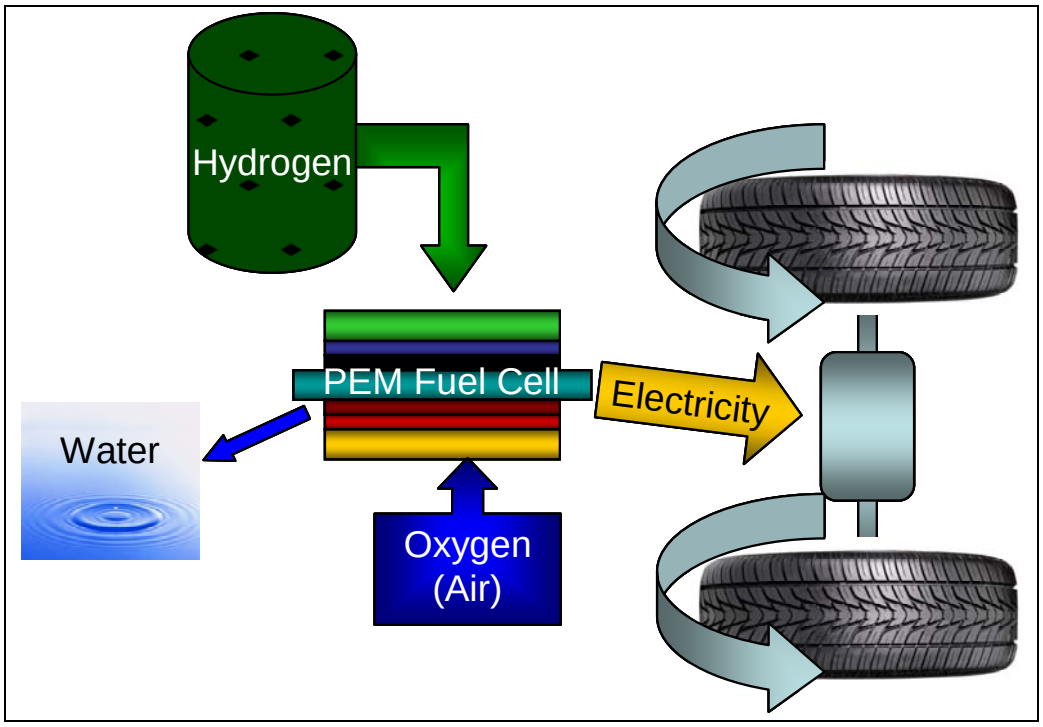


Figure 2—Basic Operation of a Hydrogen Fuel Cell for Automobiles

Hydrogen can also be used to power vehicles with internal combustion engines (ICEs), much as natural gas is currently used. At least two major automobile companies are working to develop and commercialize hydrogen ICE vehicles. Hydrogen ICE vehicles face the same hydrogen storage issues as fuel cell vehicles. Presently the cost of a hydrogen ICE vehicle is less than 25 percent of a hydrogen fuel cell vehicle. Compared to gasoline ICEs, hydrogen ICEs offer better mileage, do not consume fossil fuels and have extremely low emissions.[16]

2.0 Why Hydrogen?

The CA H2 Net Blueprint Plan has identified a number of significant benefits associated with implementing a hydrogen highway network. Hydrogen can greatly reduce our dependence on petroleum, provide numerous environmental and public health benefits, and create economic opportunities including new jobs in California.

2.1 Energy Diversity and Security Benefits

2.1.1 Hydrogen is an Integral Part of California's Long-Term Energy Strategy

California's transportation sector is nearly 100 percent dependent on gasoline and conventional diesel, both of which are nonrenewable and in finite supply.

Demand for these fuels in California alone has grown nearly 50 percent in just the last 20 years and will continue to grow. At the beginning of this decade, California had a population of 33.8 million people, driving 24 million registered vehicles, and consuming more than 17 billion gallons per year of gasoline and diesel fuel. By 2020, it is projected that 45.5 million Californians will operate 31.5 million vehicles consuming about 24 billion gallons of gasoline and diesel fuel.[17]

California's petroleum refining capacity has not kept pace with this demand. In fact, since the mid-1990s, in-state refining capacity has decreased nearly 20 percent, and California has shifted from being a net exporter of petroleum to a net importer.[18] During this period, a combination of refinery outages, marine and distribution constraints and other factors has led to volatile gasoline and diesel prices.

Several options are available to reduce the demand for petroleum transportation fuels. Conservation through the production of more fuel efficient motor vehicles is an effective means of reducing demand for petroleum. Encouraging greater use of available, non-petroleum fuels, such as natural gas and synthetic diesel fuel, can also reduce petroleum demand. Together, these near-term approaches may be able to keep the demand for petroleum fuels from increasing above current levels over the next two decades. Beyond the near-term, greater use of non-petroleum fuels will be necessary to meet the ever growing demand for clean transportation. A detailed assessment by the California Energy Commission and the Air Resources Board showed that, from an environmental and economic standpoint, hydrogen fuel cell vehicles provide an attractive long-term approach for continuing to reduce California's petroleum dependence.[19]

Figure 3 illustrates the impact of near-term measures to reduce California's dependence on petroleum. The petroleum reduction goal cannot continue to be met with near-term remedies after 2035 without additional actions. The increase in petroleum demand after 2035 is due to California's growing population and increased vehicle usage.

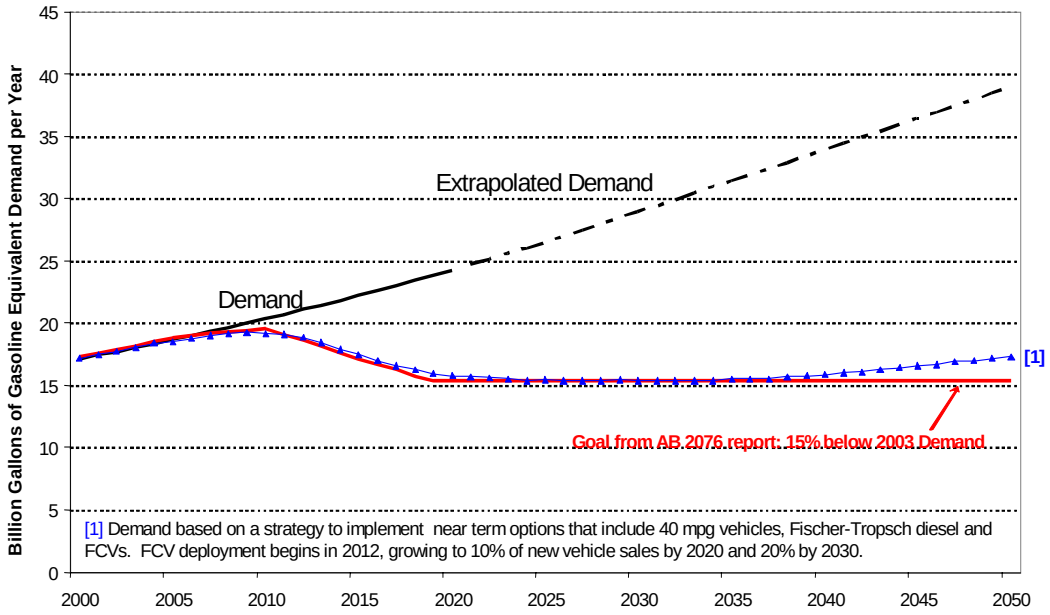


Figure 3—Growth in Demand for On-road Petroleum Fuels[20]

2.1.2 Hydrogen Can Diversify and Stabilize California's Energy Supply

Hydrogen can diversify and stabilize California's energy sector and the supply of transportation energy. Hydrogen occupies a unique niche at the confluence of transportation, electricity, and heating energy. For example, hydrogen "energy stations" are electricity production units that can also provide heating, cooling and power for homes and businesses, while producing enough additional hydrogen that can be used to fuel vehicles.

Hydrogen is an energy carrier so it can be used to store, move and deliver energy in a usable form to consumers. In this manner, hydrogen can be used to store renewable energy that is intermittent in nature for times periods when the demand exceeds the electricity supplied by the renewable resource.

2.1.3 Hydrogen Can Be Produced From Renewable Resources

An infrastructure based on hydrogen and renewable resources is inherently sustainable in nature. The term "renewable resources" (or simply "renewables") refers to resources such as wind, solar, geothermal, and waste resources such as biomass. All of these types of renewable resources are available in California and can be used to produce hydrogen. Hydrogen produced from renewable resources has no emissions of any pollutants, and reduces reliance on limited resources such as oil and natural gas. Further, to the extent California takes the lead in developing technology to produce hydrogen from renewable resources, our state

is in an attractive long-term economic position as demand for such technology is expected to grow significantly worldwide.

2.2 Environmental Benefits

To make a fair comparison of the full environmental impacts of various motor vehicle types requires characterization of the "source-to-wheel"[21] emissions. Figure 4 illustrates the steps included in the source to wheel emission calculations.

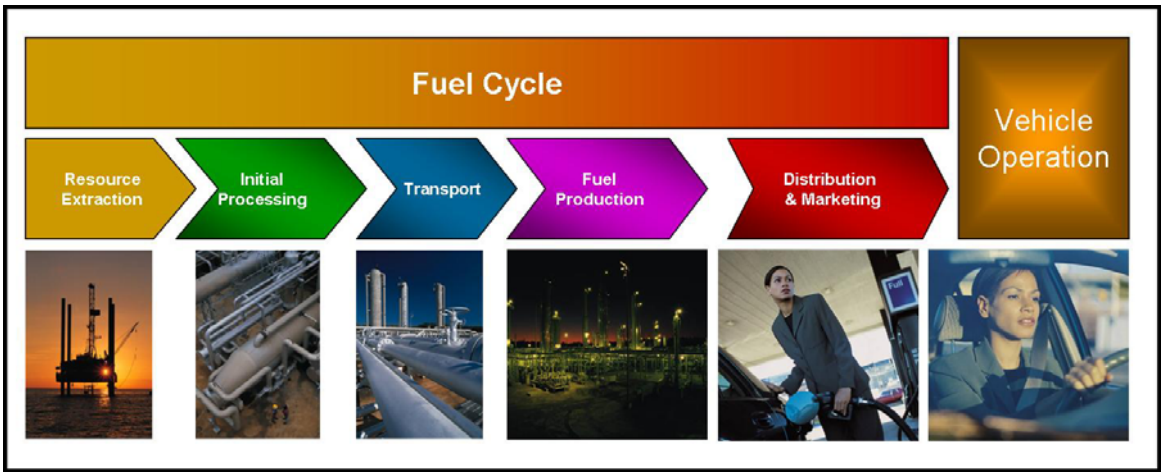


Figure 4—Emissions Illustration (Source-to-Wheel)[22]

The source-to-wheel analysis includes the steps in the fuel cycle and the end use of the fuel. The steps include extraction and processing of the fuel, transport of the fuel to the point of use, any additional processing that is needed, fueling the vehicle and vehicle operation. Based on this type of analysis, the environment benefits of using hydrogen to power vehicles or generate electricity fall into two major categories 1) reduction of smog forming and toxic emissions, and 2) reduction of greenhouse gas emissions.

2.2.1 Hydrogen Can Reduce Smog-forming and Toxic Emissions

The use of hydrogen as a transportation fuel can result in lower emissions of criteria pollutants when compared to those from petroleum fuels. The smog-forming and toxic emissions benefits are dependent on the systems and materials used to produce and consume hydrogen. If hydrogen is produced using electrolysis and the electricity is derived from renewable resources then the source to wheel emissions are zero—the entire fuel cycle is sustainable. Relative to gasoline refining, particulate matter emissions can be higher if hydrogen is generated by electrolysis dependent on electricity derived from coal. For the entire source-to-wheel analysis, hydrogen vehicle emissions of oxides of nitrogen, volatile organic compounds and carbon monoxide are less than gasoline or diesel, while the relative comparison for particulate matter depends on how the hydrogen is produced.

Distribution emissions in the hydrogen fuel cycle are only important if the hydrogen is produced in a central plant and has to be distributed by gasoline and diesel trucks. Distribution emissions are zero if the hydrogen is produced where it is used (called distributed generation) or if the hydrogen is transported from a central location by a zero emission vehicle.

Fueling emissions are never a factor in the hydrogen fuel cycle because any hydrogen that escapes during fueling is nontoxic, unlike emissions from petroleum-based fuels.

Tailpipe emissions are zero if hydrogen is used in a fuel cell vehicle. The only emission is water. The emissions consist only of only near-zero amounts of oxides of nitrogen in a hydrogen combustion engine.

In contrast, California's 24 million gasoline- and diesel-fueled vehicles directly or indirectly cause a variety of serious pollution problems in our state. Adverse environmental impacts occur during virtually every step associated with using these vehicles: from the beginning of the fuel production phase to the tailpipe. The refining of petroleum into gasoline and diesel fuel results in emissions of reactive organic compounds, including toxic compounds, oxides of nitrogen and particulate matter. Refineries are typically one of the largest stationary sources of emissions in California. The distribution of gasoline from the refinery to the retail service station results in fuel evaporation emissions at every point of transfer, including transfer to the car. Burning petroleum fuels in vehicles results in emissions of volatile organic compounds, some of which are toxic, oxides of nitrogen, carbon monoxide, and particulate matter.

This discussion points to the importance of producing hydrogen in the most environmentally sound manner. Zero emitting options are available such as solar/electrolysis, which can result in zero emissions for the entire fuel cycle.

2.2.2 Hydrogen Can Reduce Greenhouse Gas Emissions

As with smog-forming emissions, the fuel cycle greenhouse gas (GHG) emissions of hydrogen vehicles depend on the method of hydrogen production. In this case emissions also depend on what type of vehicle uses the hydrogen, because fuel cell vehicles are more efficient than combustion vehicles that burn hydrogen. And both hydrogen fuel cell and ICE vehicles are more efficient than conventional gasoline vehicles.

Shown in Figure 5 are the results of an analysis of the fuel cycle greenhouse gas emissions of hydrogen compared to gasoline, for both fuel cell and hydrogen internal combustion engine (ICE) vehicles. Notable is that production of hydrogen from renewable-based electricity results in near zero emissions. Reforming of natural gas also results in lower fuel cycle greenhouse gas emissions. However, production of hydrogen using grid electrolysis results in greater greenhouse gas emissions than gasoline. Again this points out the importance of developing the CA H2 Net using the lowest emitting technologies for producing hydrogen.

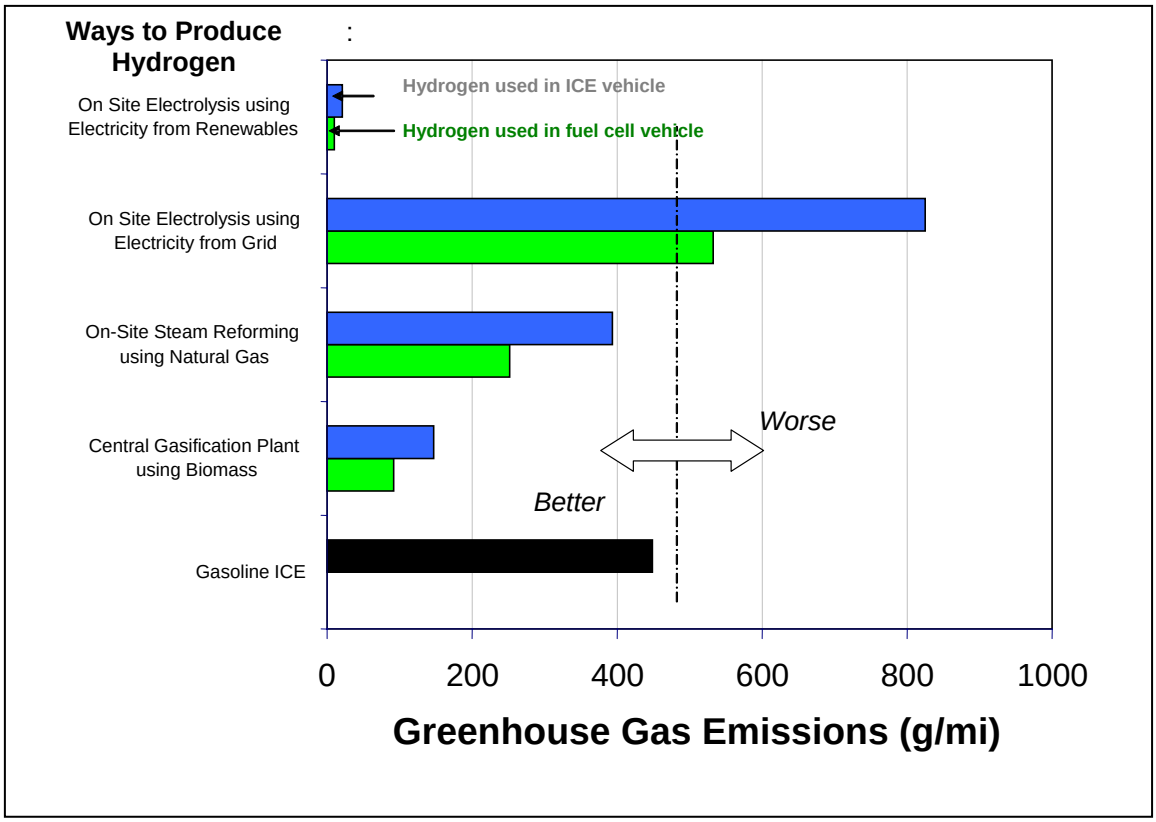


Figure 5—Source-to-Wheel Greenhouse Gas Emissions[23]

2.3 Economic Development Benefits

California has a long history of being at the forefront of emerging high-technology industries. State officials have recognized that these industries can create jobs as technologies develop and flourish in the world marketplace. More than 100 companies are working on prototype hydrogen-related technologies in California; examples include hydrogen production systems, fuel cells, hydrogen storage systems, and safety-related devices. Many companies have initiated similar efforts in other states. If California continues to lead in creating demand for hydrogen fueling stations and products, companies with related technologies are more likely to choose our state to locate new technology centers and manufacturing facilities. Expansion of hydrogen-related research, development and demonstration efforts will help generate new jobs, businesses, and industries in California.

2.4 Educational Benefits

Just as California is home to the world's leading businesses and industries, so too is it home to some of the world's finest universities. The University of California (UC) and California State University (CalState) systems have well-established programs related to the development of the hydrogen economy and its attendant technologies. California's universities have been at the forefront in engineering vehicle systems; fuels development, production, and distribution; emissions

testing; traffic modeling and infrastructure development; and more. They are also among a cadre of early-adopters and testers of hydrogen technologies and will be essential components to the early-phase rollout of the CA H2 Net. Integrating the UC and CalState systems into the development of the CA H2 Net will help sustain their vital role in the developing hydrogen economy, as well as serve to attract the world's best researchers and educators in the field.

3.0 Key Findings of the Blueprint Plan

The key findings of the Blueprint Plan outline an approach that is thoughtful and prudent. The Advisory Panel suggested several crucial points to the development of the CA H2 Net such as gradually building up the numbers of hydrogen stations and vehicles in phases, regularly reviewing the progress of the CA H2 Net, setting renewable content and GHG emissions goals for the hydrogen production, leveraging existing alternative fuel activities and building partnerships that are inclusive of government, industry, academia and advocacy groups. The EO Team has incorporated the wise suggestions of the Advisory Panel and included necessary legislative and funding needed to sustain California's leadership.

3.1 Points of Consensus from the Advisory Panel

Members of the Advisory Panel represented a diverse group of private- and public-sector stakeholders having many interests in the commercialization of hydrogen fuel and hydrogen-fueled products. They were asked to provide guidance to the Topic Teams and the EO Team. Given the Panel's diverse make up, it is significant that members were able to reach agreement on a broad range of issue areas, including:

- The CA H2 Net will continue to put California, its businesses, and universities in a world-class leadership position for the successful introduction of hydrogen technologies.
- The CA H2 Net should use a long-term, multi-phased, sustainable approach to develop hydrogen technologies.
- The CA H2 Net program will make use of existing alternative fuels (e.g. such as natural gas and ethanol) and emerging near and mid-term technologies to expand hydrogen use.
- Investment in hydrogen infrastructure is manageable.
- The CA H2 Net program should investigate a variety of hydrogen production options.
- Hydrogen vehicle introduction will depend on technology and cost readiness as well as consumer acceptance.

- Government fleets, private fleets and "early adopters" should be encouraged to purchase hydrogen vehicles based on technology and cost readiness.
- The CA H2 Net should include energy station concepts.
- The CA H2 Net should achieve a 30 percent reduction in GHG emissions relative to comparable uses of today's fuels and technologies, and utilize 20 percent renewable resources in the production of hydrogen for use in vehicles by 2010.
- The CA H2 Net will best be accomplished by fostering public-private partnerships.

3.2 A Multi-Phase Approach: Short-Term Plan With a Focus on Long-Term Objectives

A key conclusion reached by the EO Team as well as the Advisory Panel was that the transition to hydrogen fuel in California will best be accomplished through a phased approach over several years. The successive phases will include building up the number of hydrogen fueling stations as more hydrogen-fueled vehicles and products are deployed. The overall approach will require a long-term commitment that should begin now with Phase 1. Regularly scheduled assessments of the CA H2 Net progress will help ensure success while deploying 250 hydrogen fueling stations in California, as envisioned in Executive Order S-07-04.

California is using and will continue to employ a station build up philosophy. The California station build up philosophy states that the fueling stations will initially be clustered in urban areas with a few stations distributed between the areas to link them. In California, the stations will initially be located in the San Francisco Bay Area—Sacramento regions and the Los Angeles—San Diego regions. In this way consumers can freely travel within these urban areas and commute between the two. This approach will give the majority of Californians the opportunity to easily use hydrogen cars. Table 1 provides an overview of the three recommended phases. This is followed by a description of Phase 1 and a brief overview for Phases 2 and 3.

Table 1—Estimated Numbers of Hydrogen Products and Stations by Phase

Type of Hydrogen-Fueled Vehicle or Product	Number of Units Targeted / Estimated for Deployment (by Phase)		
	Phase 1: 50 to 100 Stations	Phase 2: 250 Stations (w/ Initial Lower Usage)	Phase 3: 250 Stations (w/ Expanded Usage)
Light-duty FCVs and ICEVs from major manufacturers.	2,000	10,000	20,000
Heavy-duty FCVs or ICEVs.	10	100	300
Stationary and off-road vehicle applications.	5	60	400
FCV = Fuel Cell Vehicle ICEV = Internal Combustion Engine Vehicle			

3.2.1 Description of Phase 1

The goal for Phase 1 is to establish a network of 50 to 100 stations in California. Currently there are 39 stations that are either existing or planned for completion in the next two years. Therefore, the efforts of Phase 1 will focus on building up to 61 additional hydrogen stations in California. By 2010, this will result in a statewide network of 50 to 100 hydrogen fueling stations that will be located in a manner to maximize hydrogen usage ("throughput," or volume dispensed). The number of stations is necessary to establish a network broad enough to support many small fleets.

Phase 1 stations will primarily serve fleet vehicles rather than the general motoring public. Early Phase 1 hydrogen vehicles are likely to be placed within fleets owned and operated by the State of California, other government agencies, and private companies and individuals with vested interests in hydrogen vehicles. Phase 1 progress and results will be reviewed every two years to assess the progress of vehicle and energy station manufacturers.

The number of stations sited will depend on the introduction rate of hydrogen-fueled vehicles. The numbers and locations of stations in Phase 1 are intended to fuel up to 2,000 light-duty vehicles and 10 heavy-duty vehicles. The number of vehicles is based on estimates provided by members of the California Fuel Cell Partnership and individual manufacturers. In addition, the California Stationary Fuel Cell Collaborative estimates that five "energy stations" with stationary fuel cells will be deployed during Phase 1. Energy stations are a single unit that includes a stationary power source, such as a fuel cell, and a hydrogen fueling station.

For illustration purposes, Phase 1 placement of fueling stations in Northern and Southern California was mapped in Figures 6 and 7. The Northern California map (Figure 6) shows nine existing or currently planned hydrogen stations (red dots), and ten additional stations (black dots) as they might be sited in the Bay Area and Sacramento in Phase 1 of the CA H2 Net. The Southern California Map (Figure 7) shows 21 existing or currently planned stations in the Los Angeles area and 10 additional stations as they might be sited in Phase 1. Together, these two maps illustrate a minimum 50-station network for the major population centers of Northern and Southern California. An additional 50 stations in Phase 1 would be placed in locations that need support for hydrogen-fueled vehicles and to link the urban areas to construct a fueling network. The station network that includes a concentration of stations in urban areas and a limited number of stations to link those urban centers will allow vehicles to roam between the urban areas without being limited by a vehicle's range.

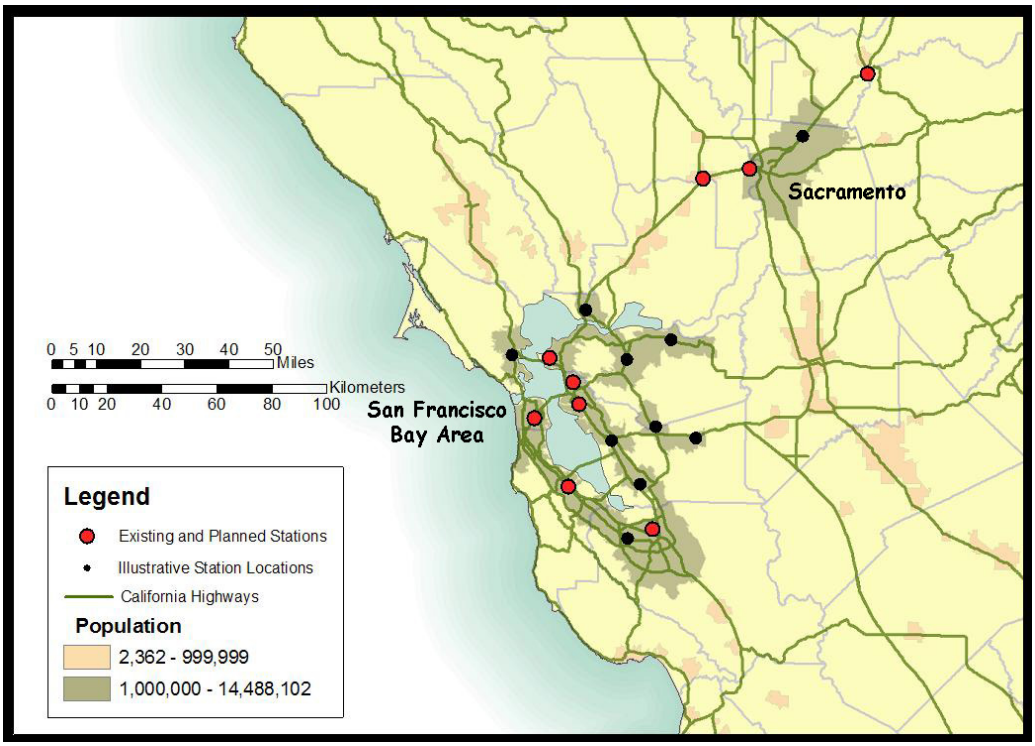


Figure 6—Example of Phase 1 stations in Northern California based on population density and existing gasoline stations[24]

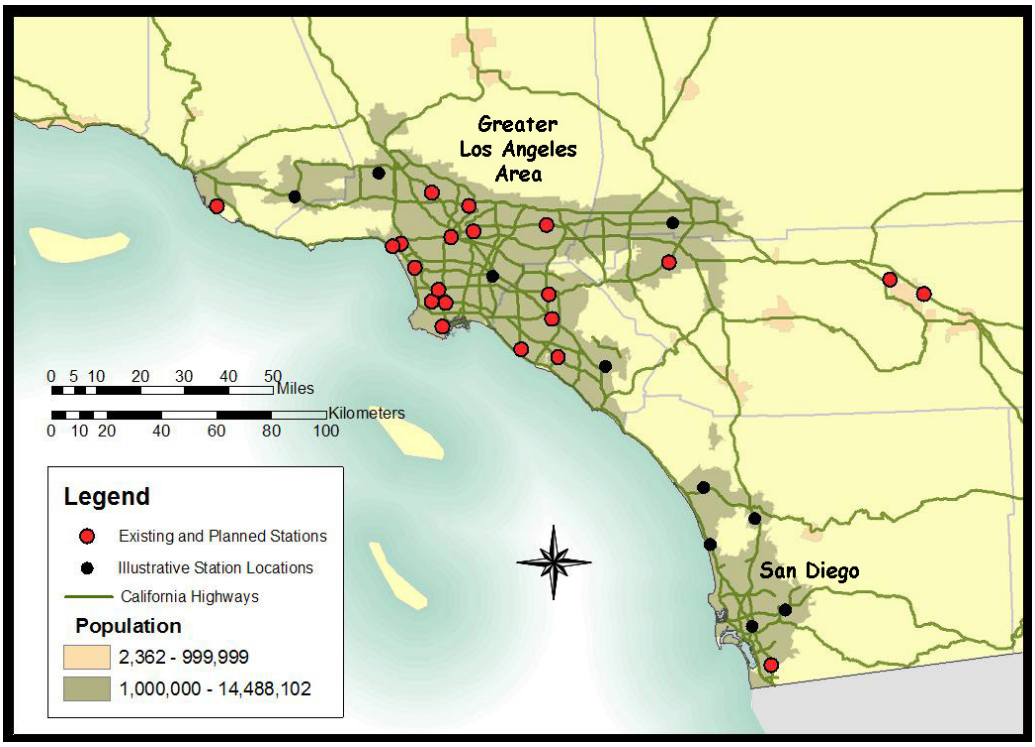


Figure 7—Example of Phase 1 stations in Southern California based on population density and existing gasoline stations[25]

The Phase 1 stations will utilize a mix of hydrogen-production technologies that can be evaluated in real-world use by energy companies to assess commercial viability. Some of the Phase 1 hydrogen stations will include energy stations. Energy stations that are powered by hydrogen or a hydrogen-containing fuel, such as natural gas, can provide fuel to hydrogen vehicles and electrical power to the grid or to nearby buildings.

To the maximum extent possible, renewable energy sources will be used to produce the hydrogen. Specific criteria for achieving environmental benefits are discussed in detail in Volume II.

3.2.2 Description of Phases 2 and 3

Embarking on Phase 2 is contingent on the completion of Phase 1 and the results of the biennial assessments. A network of 250 hydrogen stations and 10,000 hydrogen vehicles marks the exit gate for Phase 2. The vehicle-to-station ratio is similar to that in Phase 1, but with expanded numbers of vehicles in broader applications, and an expansion in energy station deployments. Also in the Phase 2 time frame, hydrogen home fueling stations (similar to home fueling now being commercialized for natural gas vehicles) may begin to play an enabling role for the CA H2 Net. These may even be small-scale residential energy stations that allow homeowners to fuel their vehicles while also powering, heating or cooling their homes.

In Phase 3, the number of stations is anticipated to remain constant while the number of hydrogen end uses increase. End uses of hydrogen include cars, buses and off-road applications. The number of vehicles is expected to double from Phase 2 to Phase 3 to equal a total of 20,000 cars. The higher ratio of vehicles to stations (80:1) is indicative of a doubling in "capacity utilization" (percentage of a station's total available hydrogen that is used) for the total station network. Phase 3 also assumes an expanded role for energy stations. Early stage development of all hydrogen stations will focus on regional network clusters in key Northern and Southern California urban areas, but these regional clusters will ultimately be bridged to form a comprehensive state network.

As the statewide network of hydrogen stations is built up in Phases 2 and 3, strategic stations that link large urban centers will play a more prominent role in the CA H2 Net. A statewide bridging network is envisioned that will focus on station deployments along Interstates 5, 10, 15, and 80.

3.3 Early Risks Must Be Shared

Implementation of hydrogen transportation and a hydrogen economy are not without challenges. For example, today's prototype hydrogen cars have high costs and technology limitations that can hinder commercialization. Cost, durability and hydrogen storage systems are among the biggest challenges. The investment by auto manufactures and the U.S. Department of Energy to solve these challenges demonstrates that there is a collective belief that they will be overcome. The CA H2 Net is an important part of making California the place to demonstrate and advance the vehicle technology so that we realize the cumulative benefits as quickly as possible.

The current pace to develop hydrogen-fueled vehicles and products is still hindered by the need to solve the so-called "chicken-or-egg" question: which should come first, commercialization of vehicles that run on hydrogen, or building of fueling stations that dispense it? Who should take the initial risk with expanded investments—hydrogen producers or vehicle manufacturers? What is the appropriate role of the government? Past experience in California with clean, alternative fuels leads to a clear conclusion: the early risks must be shared.

The benefits associated with hydrogen have prompted government organizations and private companies across the globe to pursue hydrogen technologies and build hydrogen stations. Nowhere is progress more impressive than in California. Private industry has invested heavily in California and learned many valuable lessons. The State must take advantage of industry experience and where possible, maximize future investments.

For example, the state should take advantage of the experiences station owners have shared regarding siting hydrogen stations to date. The average "public access" hydrogen station can easily take up to eighteen months to permit. In contrast, gasoline stations usually take only 12–14 months to establish yet require three more permits than hydrogen stations. The State may be able to reduce the

time to establish hydrogen stations by adopting a statewide uniform permitting process and regulatory approvals of hydrogen stations.

The simplification of the permitting process should be based on the adoption and consistent implementation of regulations, codes and standards for fire, life, and safety. These types of measures that the State can adopt will expedite the safe and effective deployment of stations by clearly defining the environment within which station developers must operate.

The State has a responsibility to implement as many non-financial incentives as possible but should also financially invest in our future if it is to be sustainable. We must invest financially now if we are to see the California environment and economy grow together.

3.4 Investment in Hydrogen

Today 11 hydrogen fueling stations are operating in Southern California and 5 in Northern California that support early demonstration programs. Most stations are not presently accessible to the public. Figure 8 illustrates the location of the hydrogen stations present in California.

Figure 8—Map of hydrogen stations in California.[26]

Plans are underway to expand the number of stations to 39 within the next two years. As part of this expansion, the South Coast Air Quality Management District is partially funding construction of several new stations in the Los Angeles area. The U.S. Department of Energy is providing a 50 percent cost share for 19 new hydrogen fueling stations. Several members of the private sector are planning a few new energy stations as part of the emerging distributed energy generation market.

All major vehicle manufacturers are investing heavily in fuel cell vehicle technology development. So far almost 90 prototype fuel cell vehicles have been placed on California's roads as part of demonstrations (e.g. University of California, the cities of Los Angeles and San Francisco, and the California Fuel Cell Partnership) to date. The number of fuel cell vehicles is expected to increase to as many as 300 within the next three years, and could increase to about 1,200 by 2010. Seven fuel cell transit buses have been ordered and will begin operating this year.

Hydrogen internal combustion engine vehicles (H2ICEs) have been developed by companies such as BMW and Ford. In addition, companies such as Quantum Technologies and the Hydrogen Car Company are producing after-market H2ICEs, which could supplement the market provided they can meet certain certification standards. If mass-produced, H2ICE vehicles could serve as a lower cost (compared to fuel cell vehicles) bridging technology to introduce the public to hydrogen, while expanding the demand for hydrogen fuel from the CA H2 Net. It is estimated that as much as $2 billion has been expended or committed towards hydrogen vehicles and fueling infrastructure in California through these existing programs.[27] Funding for these efforts is being cost shared through two primary sources: the R&D dollars of private companies that have vested interests in hydrogen (for example, automobile manufacturers and energy companies), and their government partners, including state agencies.

3.4.1 Funding Required to Expand Fueling Stations and Vehicles

The CA H2 Net is based on a phased approach in which fueling stations need to be available to serve hydrogen vehicles as they emerge from prototype demonstrations to commercial production. To allow hydrogen vehicles to operate freely within and between major urban areas of California, 50 to 100 stations are needed by 2010. Between now and then, the number of hydrogen vehicles will be growing, however it will be well into the next decade before enough vehicles will be on the road to fully utilize each station and provide an adequate return on investment to the station owner. Yet without a widely distributed network of stations now, growth in the number of hydrogen vehicles will be hindered due to lack of fuel availability. This situation ("which comes first, the stations or vehicles?") suggests a role for government to share risk and help launch these new hydrogen industries whose success will benefit all Californians. Experience with the fuel station demonstration programs sponsored by the U.S. Department

of Energy suggests a 50/50 cost share with energy providers will stimulate private sector investment in the expansion of the CA H2 Net to 100 stations.

On the vehicle side, hydrogen vehicles are not yet cost competitive with conventional vehicles. Reductions in cost must occur through continued research, development and demonstration before hydrogen vehicles become commercially available. For a FCV to be cost competitive with conventional vehicles, automakers must be able to produce fuel cell power at $50 per kilowatt. Due to significant investment in R&D by government and industry over the last several decades, the cost of fuel cell power has dropped from over $500,000 per kilowatt to less than $500 per kilowatt today.[28] While this is significant progress, the cost of fuel cell power must still come down by a factor of ten. Companies that are working on the H2ICE technology believe their vehicles will be cost competitive sooner with conventional vehicles than fuel cells. The cost differential is already less than a factor of ten between H2ICE and gasoline ICE.

Clearly, costs are decreasing as fuel cell technologies are refined with an eye toward commercialization. However, costs are expected to remain relatively high for the 1,200 fuel cell vehicles envisioned in Phase 1. The vehicle manufacturers are expected to absorb much of these costs when placing vehicles into demonstration programs, as they have done to date.

However, many other states and countries have expressed interest in participating in fuel cell vehicle demonstration programs, both because of public interest and the hope that the home of future production of fuel cell products may occur where substantial vehicle demonstrations and infrastructure have taken root. Thus there is a competition emerging to acquire the fuel cell vehicles that will become available during the rest of this decade. Competing programs around the world are drawing the resources and attention of vehicle manufactures in many different directions.

The location of the California Fuel Cell Partnership, the University of California's and California State University's transportation and technology programs, and the U.S. DOE demonstrations in our state will help continue to draw vehicles here, as will the CA H2 Net. However, to help assure a growing number of fuel cell vehicles are placed in California to utilize the fueling network, vehicle incentives are needed. Based on the state's experience with incentives for battery electric vehicles ($5,000 to $10,000 per vehicle), and taking into consideration the higher cost of fuel cell vehicles at this stage of development, a $10,000 incentive per fuel cell vehicle is believed necessary to encourage vehicle manufactures to place additional fuel cell vehicles in California fleets.

Vehicle manufacturers could also produce lower cost hydrogen vehicles that use conventional internal combustion engines. While these vehicles are less efficient and lack some of the performance attributes of a fuel cell vehicle they still achieve emissions and petroleum reduction benefits compared to conventional vehicles. And while the incremental cost of a hydrogen ICE vehicle is estimated at $20,000 per vehicle, a $10,000 per vehicle incentive or a 50/50 cost share is believed sufficient to stimulate production.

Fuel cells can also be utilized in other applications ranging from stationary power generation to forklifts. Because of low volumes, technology development often lags for these types of applications. Incentive funds are often needed to initiate development and demonstration. State incentives proved essential to initiating the purchase of seven fuel cell transit buses. It is expected that incentives, used as a highly leveraged cost-share, would be effective in developing markets for heavy duty on-road and off-road applications for hydrogen fuel cells and hydrogen combustion engines.

3.4.2 Estimated Costs for Phase 1

The estimated cost for the State's share of implementing Phase 1 of the CA H2 Net is presented in Table 2. About half of the funds would be used to help build new hydrogen fueling stations, with the other half providing vehicle incentives. The total cost is $53.5 million spread out over five fiscal years, or about $11 million per year. The private sector is committed to the other 50 percent of the investment needed to make this program successful. Energy companies have expressed enthusiasm about participating in the CA H2 Net, especially with the coordinated, phased and thoughtful process laid out by the Blueprint Plan. Auto manufacturers have expressed the need for vehicle incentives to bring together a balance of investment between carmaker, government and fleets users. As mentioned before, cost-sharing of both stations and vehicles will draw hydrogen activity to California in the face of growing world-wide demand for demonstration projects.

Table 2—Estimated State Cost to Implement Phase 1 of CA H2 Net over 5 years

Elements of Phase 1	Total Estimated Costs (millions)	Estimated Cost Share for State (millions)
11 additional stations (note 1).	$11.0	$5.5
Next 50 stations (note 2).	$54.0	$27.0
Incentives for 1,000 light-duty fuel cell vehicles (note 3).	$10.0	$10.0
Incentives for incremental cost of 800 light-duty hydrogen ICE vehicles (note 4)	$16.0	$8.0
Demonstration of new applications for hydrogen fuel cells (note 5)		$3.0
Total Estimated Phase 1 Cost for State of California		**$53.5**

Table Notes:

1. An estimated 39 hydrogen stations are built or being planned through existing programs. 11 additional stations are needed to achieve the lower-end Phase 1 goal of 50 stations.
2. 50 additional stations will be needed to achieve the upper-end Phase 1 goal of 100 stations.
3. Industry is providing 200-300 light-duty fuel cell vehicles as part of existing industry and government programs. Incentives are needed under Phase 1 to encourage placement of an additional 1000 vehicles in California.
4. Production of lower cost vehicles that burn hydrogen in conventional engines can occur with appropriate incentives, allowing a more rapid build-up to take advantage of the CA H2 Net.
5. Funding needed to cost share development of new applications of fuel cells in transit buses, shuttle buses, and off-road equipment.

The state share of the next 11 fueling stations would be $5.5 million, based on a 50/50 cost share with energy providers (approximately $500,000 per station). The average cost of each of the next 50 stations will be about the same—slightly more than $1 million per station—yielding a state cost share of $27 million. The number of stations to be built beyond the first 50 would be determined during the regular program progress reviews, and the state's contribution could be spread out over 5 years.

Only a few hundred fuel cell vehicles are planned for demonstrations in California to date. Fuel cell vehicle incentives of $10 million would help ensure California can grow its hydrogen vehicle fleet on a path consistent with development of the fuel station network. One thousand additional fuel cell vehicles would be placed in fleets that would continue their operation for the vehicles' useful life. In addition to rapidly increasing the number of operational hydrogen vehicles, 800 hydrogen ICE vehicles would be offered subsidies. A $10,000 per vehicle subsidy is considered sufficient to acquire both types of vehicles for use in California.

Three million dollars is suggested to provide incentives for new applications for fuel cell vehicles, such as heavy duty and off-road vehicles. The incentive amount per vehicle would depend on the application. The concept is similar to the California Energy Commission electricity program (Public Interest Energy Research Program or PIER) which awards funds for projects whose success can help improve the operation and efficiency of infrastructure.

These estimated Phase 1 costs are justified by the benefits discussed in this report. These costs appear to be well within the range of funding currently associated with clean air programs in California.[29] One finding of the CA H2 Net Blueprint Plan is that private industry cannot justify investing this magnitude of private capital "based on expected returns over the near term…given the immaturity of the market, projections of product availability, and the time needed to develop (significant) throughput at hydrogen fueling stations."[30] Without government cost sharing through the CA H2 Net, Phase 1 is unlikely to be implemented.

The biennial review process will be used to assess technological and commercial readiness for both vehicles and fueling stations. This will allow the State to make informed decisions regarding incremental funding allocations for Phase 1, as well as whether or not to fund subsequent phases.

3.4.3 Estimated Costs for Phases 2 and 3

The costs to implement Phases 2 and 3 will depend on the success achieved during Phase 1. Assuming the upper limit of 100 stations is achieved for Phase 1, an additional 150 stations will be targeted for completion by the end of Phase 2. The cost of adding these additional 150 hydrogen fueling stations is estimated at approximately $76 million, reflecting a lower per-station cost as volumes increase and fueling technologies mature. Whether or not California will need to share these costs will depend on how industry views the risks and returns associated with this level of investment.

Similarly, it is not clear that vehicle incentives will be required in these later phases. Technical successes in on-board storage, fuel cell costs and durability could obviate the need for incentives. Volume II of this Blueprint Plan includes detailed discussions of the various options that may provide the funding for the implementation of the CA H2 Net. The pros and cons of each funding mechanism are also discussed. Some of those options include (but are not limited to); market-based mechanisms, subsidies, non-profits & reinforcing mechanisms.

3.4.4 The Competition[31]

California is not the only state to recognize the benefits of hydrogen and work to bring the industry home. At least thirteen states either have funding mechanisms in place or proposed that are available for hydrogen projects and most states have University researchers working on hydrogen related technologies. The Colorado Fuel Cell Research Center has leveraged $2 million in public funding to develop a project worth over $12 million. Florida presently has proposed legislation worth

over $15 million in funding and tax credits for hydrogen projects. Minnesota has a legislative proposal worth $6 million in bonds that would be used to build a wind-to hydrogen project. Even a smaller state like Hawaii has been investing in hydrogen since 1983.

The competition to become the home of the hydrogen revolution is steep. California has got to take decisive action under Governor Schwarzenegger's leadership to secure the hub of the next technology revolution.

4.0 California Hydrogen Blueprint Action Plan

The EO Team came to a number of conclusions in the form of an Action Plan that will support and accelerate the realization of the benefits of the California Hydrogen Highway Network. To capitalize on the commitment of auto manufactures to build hydrogen vehicles and the interest of energy companies to help build hydrogen fueling stations, now is the time for the State of California to provide leadership. The Action Plan follows:

- **The Governor's budget should propose the funds for Phase 1 of the CA H2 Net**. A network of up to 100 hydrogen fueling stations allowing up to 2000 hydrogen vehicles to operate freely within the state can occur with financial participation by the state. 50/50 cost sharing of fueling stations and incentives to increase the number of hydrogen vehicles placed in California can be realized with a $10.7 million dollar annual investment for 5 years.

- **Site stations, build the CA H2 Net, and procure vehicles in cooperation with stakeholders by forming a public/private partnership**. Successful implementation of Phase 1 requires cooperation and partnership with other stakeholders interested in the benefits of hydrogen. A partnership with energy providers will provide funding and expertise to build fueling stations and market the fuel. A partnership with vehicle providers will place vehicles in appropriate fleets and help assure successful operation. A partnership with other government agencies will maximize the resources needed to implement the CA H2 Net, including addressing codes and standards, siting stations, and coordinating with fire marshals and safety personnel. A public-private partnership should be defined and led by Cal/EPA.

- **Adhere to environmental goals during implementation of the CA H2 Net**. Implementation of the CA H2 Net should achieve the goals recommended by the Advisory Panel of producing hydrogen from renewable sources and reducing greenhouse gases and other pollutants relative to conventional fuels.

- **Enact legislation to support use of hydrogen for**. New legislation is needed to:
    - Establish hydrogen as a "transportation fuel"
    - Designate the State Fire Marshal's Office as the lead agency responsible for adopting hydrogen codes and standards, coordinating local authorities having jurisdiction and their permitting processes, and training emergency first responders to address hydrogen incidents
    - Amend the appeals process for station siting so that the decision of the State Fire Marshal's Office on an appeal is binding and final
- **Initiate an outreach plan**. An outreach plan to inform the public of the benefits and objectives of the CA H2 Net should be initiated.

These recommendations, along with many specific and detailed action items developed by the Advisory Panel and Topic Teams are discussed in detail in Volume II. The Action Plan provides a clear direction for implementing a successful CA H2 Net that will be the foundation for successful commercialization of a hydrogen-based economy in California.

Acronyms

CA	California
CA H2 Net	California Hydrogen Highway Network
Cal/EPA	California Environmental Protection Agency
EO	Executive Order
EO Team	Executive Order Team
EV	Electric Vehicle
FCV	Fuel Cell Vehicle
GHG	Greenhouse Gas
H2	Hydrogen
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
NASA	National Aeronautics and Space Administration
PEM	Proton Exchange Membrane
PIER	Public Interest Energy Research Program
PM_{10}	Particulate Matter $\leq$ 10 microns in diameter
R&D	Research and Development
U.S. DOE	United States Department of Energy

Appendix A—Executive Order S-7-04

EXECUTIVE DEPARTMENT

STATE OF CALIFORNIA

EXECUTIVE ORDER S-7-04
by the
Governor of the State of California

WHEREAS, hydrogen, a non-carbon energy carrier which can be made from clean renewable energy, is ideally suited to address global, regional and local energy and environmental challenges; and

WHEREAS, the State of California is a world leader in renewable energy production, efficiency and conservation, clean air and emission controls, environmental goals and planning, as well as creating, promoting and commercializing new technologies and industries; and

WHEREAS, hydrogen-powered vehicles and infrastructure can lead to energy independence; offer zero or near-zero smog-forming emissions; reduce health problems due to motor vehicle-related air pollution; reduce water pollution from oil and gasoline leaks; lower global warming pollution; improve fuel economy; quieter and smoother operation; as well as provide economic and workforce benefits to help California meet current and future energy needs; and

WHEREAS, the economic feasibility of a hydrogen infrastructure is enhanced by building hydrogen energy stations that power vehicles as well as supply electricity for California's power needs; and

WHEREAS, air pollution can cause or aggravate a wide range of serious health problems including cancer, birth defects, respiratory illnesses such as asthma and emphysema, heart and blood ailments, nervous system toxicity and early death; and

WHEREAS, children are more acutely affected by air pollution and have a higher incidence of harm from dirty air; and

WHEREAS, health problems caused by air pollution result in direct and indirect costs of hundreds of billions of dollars per year in California; and

WHEREAS, even after years of improvements in vehicle emissions technologies and effective emissions regulation, California has some of the worst air quality in the country; and

WHEREAS, much of the State of California does not meet state or federal health-based air quality standards, is at risk of not meeting federal air quality "attainment" status and may thereby lose billions of dollars in federal funds; and

WHEREAS, California is committed to Environmental Justice to ensure a clean and sustainable environment for all Californians; and

WHEREAS, the California Legislature has taken a leadership role to address petroleum dependence by passing AB 2076, which resulted in a report by the California Energy Commission (CEC) and the Air Resources Board (ARB) that found: California's oil refining capacity has not been able to keep up with growing demand for fossil fuel; the state faces a future of increasing petroleum dependence, supply disruptions, and rapid and frequent price volatility; without major efforts to reduce petroleum dependence, meeting future petroleum needs would require that California accept major expansion of refining capacity, delivery infrastructure and increased dependence on foreign energy supplies; and

WHEREAS, California is the home to the California Fuel Cell Partnership, a unique collaborative of eight auto manufacturers, four energy supply companies, two fuel cell technology companies, and seven government agencies, seeking to advance practical environmental transportation solutions with new fuel cell vehicle and hydrogen infrastructure technologies. The California Fuel Cell Partnership is the first public private partnership to test fuel cell vehicles under real day-to-day driving conditions; and

WHEREAS, California is also the home of the California Stationary Fuel Cell Collaborative, a public-private organization that includes 16 government agencies, two public electric utilities, the University of California, as well as major fuel cell technology companies, end users, energy supply companies, local government agencies and municipalities, research institutions, and developers; and

WHEREAS, state government organizations have been leading both research and commercial advances in energy and transportation technologies; and

WHEREAS, local governments and regional government agencies also are taking a leadership role to advance hydrogen and fuel cell vehicle technologies; and

WHEREAS, many of California's prestigious universities, national laboratories, and research institutions are leaders in advancing hydrogen, fuel cells, renewable energy, advanced vehicle systems and infrastructure technology through commercialization strategies and partnerships; and

WHEREAS, several studies have estimated that hundreds of thousands of manufacturing and support services jobs will be created when fuel cells gain market shares in the power and vehicle markets, and California is poised to receive many of these jobs and related investment and export opportunities because of its educated workforce and robust automotive and fuel sectors; and

WHEREAS, auto manufacturers have publicly announced their intention to commercially market "tens of thousands" of hydrogen and fuel cell vehicles within this decade, providing that a hydrogen infrastructure is available; and

WHEREAS, California has one of the nation's largest public fleets and the largest private sector vehicle market in the United States and has set a precedent of pushing for vehicle emissions reductions and clean vehicle technologies; and

WHEREAS, California's commitment to clean energy surpasses that of any other state, and California offers the best opportunity to hasten the commercialization of hydrogen and fuel cell technologies.

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, Governor of the State of California, by virtue of the power vested in me by the Constitution and statutes of the State of California, do hereby issue this order effective immediately:

IT IS ORDERED that the State of California is committed to achieving a clean energy and transportation future based on the rapid commercialization of hydrogen and fuel cell technologies; and

BE IT FURTHER ORDERED that California's 21 interstate freeways shall be designated as the "California Hydrogen Highway Network" and the California Environmental Protection Agency and all other relevant state agencies including but not limited to State and Consumer Services; Department of Finance; Business, Transportation and Housing; Education; Health and Human Services; and Resources, shall work with state legislators and key stakeholders, including local and regional government organizations, educators, energy providers, automakers, fuel cell products suppliers, financing entities, non-governmental organizations, and community based organizations including those representing Environmental Justice communities to implement this Executive Order, plan and build a network of hydrogen fueling stations along these roadways and in the urban centers that they connect, so that by 2010, every Californian will have access to hydrogen fuel, with a significant and increasing percentage produced from clean, renewable sources; and

BE IT FURTHER ORDERED that the California Environmental Protection Agency, in concert with the State Legislature, and in consultation with the California Energy Resources Conservation and Development Commission and other relevant state and local agencies, develop a California Hydrogen Economy Blueprint Plan for the rapid transition to a hydrogen economy in California due January 1, 2005, and to be updated bi-annually thereafter containing recommendations to the Governor and the State Legislature and shall include, but not be limited to, the following:

Accelerating progress in hydrogen use, including public incentives and financing mechanisms such as general obligation bonds, or revenue bonds with repayment mechanisms; joint power agreements, procurement agreements, competitive master contracts, and partnerships with public and private entities; a review of immediate financing opportunities via the California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA).

Promoting environmental benefits (including global climate change) and economic development opportunities resulting from increased utilization of hydrogen for stationary and mobile applications; policy strategies to ensure hydrogen generation results in the lowest possible emissions of greenhouse gases and other air pollutants.

BE IT FURTHER ORDERED that the State of California will commit to achieving the following by 2010:

The state will commit to negotiate with auto makers and fuel cell manufacturers to ensure that hydrogen-powered cars, buses, trucks, and generators become commercially available for purchase by California consumers, businesses and agencies including state, regional and local; and

- California's state vehicle fleet shall include an increasing number of clean, hydrogen-powered vehicles when possible to be purchased during the normal course of fleet replacement; and
- Safety standards, building codes and emergency response procedures for hydrogen fueling installations and operation of hydrogen-powered vehicles shall be in place and permit agencies, building inspectors and emergency responders shall receive appropriate training; and

- Appropriate incentives shall be provided to encourage the purchase of hydrogen-powered vehicles and to encourage the development of renewable sources of energy for hydrogen production; and

I FURTHER DIRECT that as soon as hereafter possible, this order shall be filed with the Office of the Secretary of State and that widespread publicity and notice be given to this order.

IN WITNESS WHEREOF I have here unto set my hand and caused the Great Seal of the State of California to be affixed this the twentieth day of April 2004.

/s/ Arnold Schwarzenegger

Governor of California

Appendix B—List of Contributors

Senior Review Committee

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1 Was Agency Secretary of Cal/EPA at the time the Hydrogen Highway was first initiated.

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[2] Was Chairman of the Air Resources Board at the time the Hydrogen Highway was first initiated.

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Wolfgang Weiss, Co-Chair
Phil Baxley, Co-Chair

Endnotes

[1] This is an increasingly recurring theme in the petroleum industry as evidenced by: "ChevronTexaco Warns of Global Bidding War," by Deepa Babington, Reuters, February 15, 2005; "Shell cuts oil reserves again as profits soar," by Tom Bergin, Reuters, February 3, 2005; "Shell, Exxon Tap 'High Cost' Oil Sands, Gas as Reserves Dwindle," Bloomberg, February 18, 2005.

[2] "Crude Oil and Total Petroleum Imports Top 15 Countries", United States Department of Energy—Energy Information Administration, February 23, 2003.

[3] Intergovernmental Panel on Climate Change, 2001. Third Assessment Report of the Intergovernmental Panel on Climate Change.

[4] This is an increasingly recurring theme in the petroleum industry as evidenced by: "ChevronTexaco Warns of Global Bidding War," by Deepa Babington, Reuters, February 15, 2005; "Shell cuts oil reserves again as profits soar," by Tom Bergin, Reuters, February 3, 2005; "Shell, Exxon Tap 'High Cost' Oil Sands, Gas as Reserves Dwindle," Bloomberg, February 18, 2005.

[5] "Crude Oil and Total Petroleum Imports Top 15 Countries", United States Department of Energy—Energy Information Administration, February 23, 2003.

[6] Intergovernmental Panel on Climate Change, 2001. Third Assessment Report of the Intergovernmental Panel on Climate Change.

[7] www.fypower.org/save_gasoline/.

[8] California AB 2628 proposed by Assemblymember Fran Pavley in 2004.

[9] An "energy carrier" stores, moves, and delivers energy in a useable form to consumers.

[10] Executive Order Team members are Alan C. Lloyd, PhD, Cal/EPA Secretary; Shannon Baxter Clemmons, Cal/EPA Special Advisor on Hydrogen and Renewables; and Daniel Emmett, Energy Independence Coalition's Executive Director. Cabinet Secretary Terry Tamminen led the effort in 2004 when he was Cal/EPA Secretary.

[11] The individual members of the Advisory Panel are acknowledged on the inside front cover of this report and are listed in Appendix B.

[12] The Topic Team members are individually listed at the beginning of Volume II of the California Hydrogen Blueprint Plan. The Topic Team leaders and co-chairs are listed in Appendix B.

[13] Reports are available at www.hydrogenhighway.ca.gov.

[14] California Energy Commission, *Energy Story: Chapter 20*; is available online at www.energyquest.ca.gov/story/chapter20.html.

[15] Ibid.

[16] Equivalent to the Air Resources Board's Low Emission Vehicle rating of SULEV.

[17] California Energy Commission, California Air Resources Board; *Reducing California's Petroleum Dependence, Joint Agency Report*; August 2003 (Publication Number P600-03-005f).

[18] Ibid.
[19] Ibid.
[20] Ibid.
[21] This report uses the term "Source-to-Wheel" rather than "Well-to-Wheel" that is more commonly known. Source-to-Wheel is a more accurate term to describe hydrogen production since well to wheel denotes oil well to vehicle wheel.
[22] Images illustrate fuel cycle for petroleum fuel production.
[23] Hydrogen production methods depicted in this figure represent the high and low ends of emissions impacts. This figure is representative of light-duty vehicles only.
[24] These maps are meant to illustrate station placements rather than show actual station locations. These maps show a combination of actual and hypothetical placements for planned and yet to be planned sites. Only 30 of the currently estimated 39 existing stations are shown. Many of the currently planned station sites are confidential.
[25] Ibid.
[26] Up-to-date information on the specifics of the hydrogen stations in California can be found at www.cafcp.org/fuel-vehl_map.html.
[27] This is an educated guess based on input from Advisory Panel members and individuals familiar with various programs in California.
[28] U.S. Department of Energy (www.fossil.energy.gov/programs/powersystems/fuelcells/) and Automotive News, "GM: Sequel Fuel Cell Vehicle Not Ready for Mass Production," by Jason Stein, January 09, 2005 (www.autonews.com/news.cms?newsId=11110).
[29] For example, the Governor recently signed AB 923, which expands California's Carl Moyer Program. Up to $140 million per year of incentive funding is now available to help reduce diesel-related emissions, including funding that was provided in the fiscal year 2004-2005 budget (SB1107).
[30] See Economy Topic Team report in Volume II of this report.
[31] More information on hydrogen initiatives in other states can be found at www.energyindependencenow.org/factsheets.html